

## Appendix D

### SAMPLE DECISION ANALYSIS

#### SUMMARY

This Appendix provides an example of structured multi-attribute decision analysis.

A simple example of multi-attribute decision analysis follows. Assume that a project is operating with three technical performance measures, plus cost and schedule. The equation for this case may be written:

$$\text{SCORE} = \text{WTM1} * \text{TM1} + \text{WTM2} * \text{TM2} + \text{WTM3} * \text{TM3} + \text{WT} * \text{T} + \text{WC} * \text{C}$$

where:

measure #1	WTM1	=	weight factor for technical performance
measure #1	TM1	=	normalized value of technical performance
measure #2	WTM2	=	weight factor for technical performance
measure #2	TM2	=	normalized value of technical performance
measure #3	WTM3	=	weight factor for technical performance
measure #3	TM3	=	normalized value of technical performance
	WT	=	weight factor for schedule (time)
	T	=	normalized value of schedule (development time)
	WC	=	weight factor for cost
	C	=	normalized value of cost

Assume that Option 1 in this study has the following values on each performance measure and that the range of estimates for all other options are as shown:

Option 1 Projections Options	Range of Values among all
TM1 - 2400 bps (Data rate) to 3000 bps)	(1500 bps
TM2 - 97% (Accuracy)	(95% to 98%)
TM3 - 50m (Resolution)	(5m

to 130m)

T - 36 months (Development time) (30  
months to 50 months)

C - \$5,000,000 (Life cycle cost)  
(\$3,500,000 to \$7,000,000)

Normalization of values occurs by assigning the score of 1 to the best projected value on each performance measure and 0 to the worst expectation. All other predictions are then interpolated to their intermediate values between 0 and 1. Thus the normalized predictions for Option 1 would be:

Option 1 Projections	Normalized Score
TM1 - 2400 bps (Data rate) (2400-1500)/(3000-1500) =	0.60
TM2 - 97% (0.97-0.95)/(0.98-0.95) =	0.66
TM3 - 50m (130-50)/(130-5) =	0.64
T - 36 months (50-36)/(50-30) =	0.70
C - \$5,000,000 (7-5)/(7-3.5) =	0.57

Note that the value subtracted from the Option 1 estimate in the numerator of each equation is the estimate of the worst option on that performance measure. Thus, in the cases of technical performance measures one and two, the lowest estimate is used since more is better. Conversely for TM3, schedule and cost, less is better and the highest estimate among all options is subtracted in the numerator.

In order to finalize the score for Option 1, the relative weights of the performance measures are needed. Assume for this example that these values were given by the customer as:

Performance Measure	Relative Importance
TM1 - Data rate 0.20	
TM2 - Accuracy 0.35	

M3	-	Resolution
	0.20	
T	-	Development time
	0.10	
C	-	Life cycle cost
	0.15	

This list indicates that accuracy is of the greatest concern, and development time for this range of values is relatively unimportant. Now the score for Option 1 may be calculated as:

$$\text{SCORE}(1) = 0.20*0.60 + 0.35*0.66 + 0.20*0.64 + 0.10*0.70 + 0.15*0.57$$

$$\text{SCORE}(1) = 0.63$$

The scores for all other options may be calculated in the same manner. A complete treatment of multi-attribute decision analysis has been derived by Keeney and Raiffa, "Decisions with Multiple Objectives: Preferences and Value Tradeoffs," which is listed in Appendix E, "References," "Selected References."

## REFERENCES

### SUMMARY

This Appendix provides a selected and annotated list of references and directives which are pertinent to systems engineering and project management.

## **NASA Policy Directives**

NPD 2820.1, NASA Software Policies

NPD 7000.3D, Allocation and Control of Agency Resources

NPD 7120.4A, Program/Project Management

## **NASA Procedures and Guidelines**

NPG 7120.5A, NASA Program and Project Management Processes and Requirements

## **NASA Internal Publications**

SED Engineering Handbook EHB-1, Systems Engineering Division Product Assurance Plan, Langley Research Center, Systems Engineering Division, January 1990

NASA Systems Engineering Handbook, SP-6105, June 1995.

TL-790.M57 1992 The NASA Mission Design Process - A Guide to the Concept, Mission Analysis, and Definition Phases, Draft, Goddard Space Flight Center, Engineering Directorate, December 1992

MSFC-HDBK-1912, Systems Engineering Handbook - Volume 1 - Overview and Processes, George C. Marshall Space Flight Center, Systems Analysis Division, December 1994

MSFC-HDBK-1912, Systems Engineering Handbook - Volume 2 - Tools, Techniques, and Lessons Learned, George C. Marshall Space Flight Center, Systems Analysis Division, December 1994

## **Langley Policy Directives**

LAPD 7120.2, Authority and Responsibilities of Managers of Small Space Flight Projects

## **Langley Procedures and Guidelines**

LAPG 5000.2, Procurement Initiator's Guide

LAPG 5300.1, Space Product Assurance

LAPG 7320.1, Engineering Drawing System

## **Selected References**

1. Barthelemy, Jean-Francois M., ed.: Recent Advances in Multidisciplinary Analysis and Optimization, Parts 1-3. NASA Conference Publication 3031, 1989. Proceedings of a symposium on multidisciplinary analysis held at Langley Research Center in September 1988.
2. Blanchard, Benjamin S., and Fabrycky, Wolter J.: Systems Engineering and Analysis. Second Edition, Prentice-Hall, Inc., 1990.
3. Charette, Robert N.: Software Engineering Risk Analysis and Management. Intertext Publications/McGraw-Hill Book Company, 1989.
4. Gibson, J. E.: How to do Systems Analysis, 1989.
5. Griffin, Michael D., and French, James R.: Space Vehicle Design. American Institute of Aeronautics and Astronautics, 1991.
6. Hoban, Francis T., and Lawbaugh, William M., eds.: Readings in Systems Engineering. NASA SP-6102, 1993.
7. Keeney, Ralph L., and Raiffa, Howard: Decisions with Multiple Objectives: Preferences and Value Tradeoffs. John Wiley and Sons, 1976.
8. Kerzner, Harold: Project Management - A Systems Approach to Planning, Scheduling, and Controlling. Second Edition. Van Nostrand Reinhold Company, 1984.
9. Lacy, J. A.: System Engineering Management: Achieving Total Quality. McGraw Hill, 1992.
10. Lewis, E. E.: Introduction to Reliability Engineering. John Wiley and Sons, 1987.
11. Phadke, Madhav S.: Quality Engineering Using Robust Design. PTR Prentice Hall, 1989.
12. Pittman, Bruce: Dynamic System Engineering: A Guide to Understanding and Implementing System Engineering. Pittman and Associates, 1991.
13. Rumbaugh, James; Blaha, Michael; Premerlani, William; Eddy, Frederick; and Lorensen, William: Object-Oriented Modeling and Design. Prentice Hall Inc., 1991.
14. Sage, Andrew P.: Systems Engineering. John Wiley and Sons, 1992. Focuses on systems methodology, design, and management and emphasizes the process of systems engineering rather than the product.

15. Walters, J. M., et al.: Addendum to the LASE Follow-on Pre-Phase A Study, 1993.
16. Wymore, A. Wayne: Model-Based Systems Engineering. CRC Press, 1993.
17. Anonymous: System Engineering Process. Center for Systems Management, Inc., 1993.

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